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Comparative Cost of Steel Skeleton and Solid Masonry Walls for School Buildings

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COMPARATIVE COST
OF
STEEL SKELETON AND SOLID MASONRY WALLS FOR SCHOOL BUILDINGS

BY

ROY ERNEST PICKETT

THESIS

FOR

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Roy Ernest Pickett

ENTITLED Comparative Cost of Steel Skeleton and Solid Masonry Walls for School Buildings

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Architectural Engineering

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Comparative Cost of Steel Skeleton and Solid Masonry Walls for School Buildings.

Introduction - With the increasing use of steel in building operations the question arises, is it economical to use a steel structure and carry the walls and floors on this instead of supporting all loads on the masonry walls? The great height to which buildings are now being carried makes steel structures necessary because of the large walls and piers that would be required to support the loads, which would consume an excessive amount of floor area. But for buildings up to four or five stories in height, is it not cheaper to make the walls large enough to support the whole building?

According to Kidder "A careful comparison of the cost per cubic foot of a large number of buildings estimated for both fireproof construction and ordinary construction seems to indicate that the cost of fireproof construction is from 9 to 13 percent greater than that of the wooden joist construction and that, in the case of such buildings as stores and warehouses, as small an amount as 5 percent will cover the difference in cost."

General Considerations - This thesis has been limited to a discussion of walls for school buildings. Through the kindness of Mr. Jos. C. Llewellyn, Architect, a complete set of plans for the East Side High School, Aurora, Ill., were obtained. This building was chosen as a typical school building with solid masonry walls. Without changing the external appearance, this building was re-designed with steel columns and girders to carry the floor and roof loads, the walls being self- supporting. The new Chicago Building Ordinance (1911) has governed the

design. The general design, foundation, floors, roof, windows, etc. in both types of building are the same so that the difference in cost of erecting the two buildings will be in the variation in size of exterior walls and the difference in construction of the interior walls. The labor charge will vary considerably in the two types of construction.

Acknowledgement is hereby made to the following companies for valuable information given:

English Brothers	Champaign, Ill.
Morava Construction Company	Chicago, Ill.
New York Blower Company	" "
Twin City Roofing Company	Champaign, Ill.
V. Jobst & Sons	Peoria, Ill.
James Stewart & Company	St. Louis, Mo.
Geo. A. Fuller Company	Chicago, Ill.

Computation of Loadings Common to Both Types of Construction

Weight of Roof Truss

Trusses 20'-6" on centers.

No.	Size of Angles	Length in Feet	Volume - Cu. Ft.
4	5" x 3" x 3/8"	20	1.60
2	2-1/2" x 2-1/2" x 1/4"	3	.05
6	3" x 3" x 1/4"	5	.30
2	"	6	.12
4	"	9.5	.38
2	"	10.	.20
1	"	8	.08
4	3-1/2" x 3-1/2" x 5/16"	14	.815
4	3" x 3" x 1/4"	9	.36
			3.905

Total weight of one truss = 3.905 x 490 = 1920 lbs.

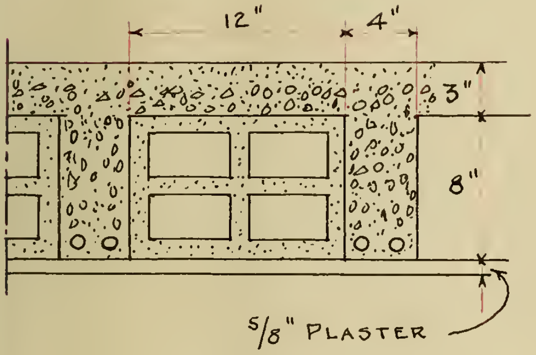
1/2 Weight of Roof Carried By One Truss

Tile	2 x 20.5 x 26 x 10	Tile - 10# per sq.ft.	10,600 lbs.
Sheathing	2 x 20.5 x 26 x 2 x 4.5		9,600 "
Purlins	11 x 20.5 x 7 x 4.5		7,100 "
Truss			1,920 "
			29,220 "

Total Floor Load of School Room

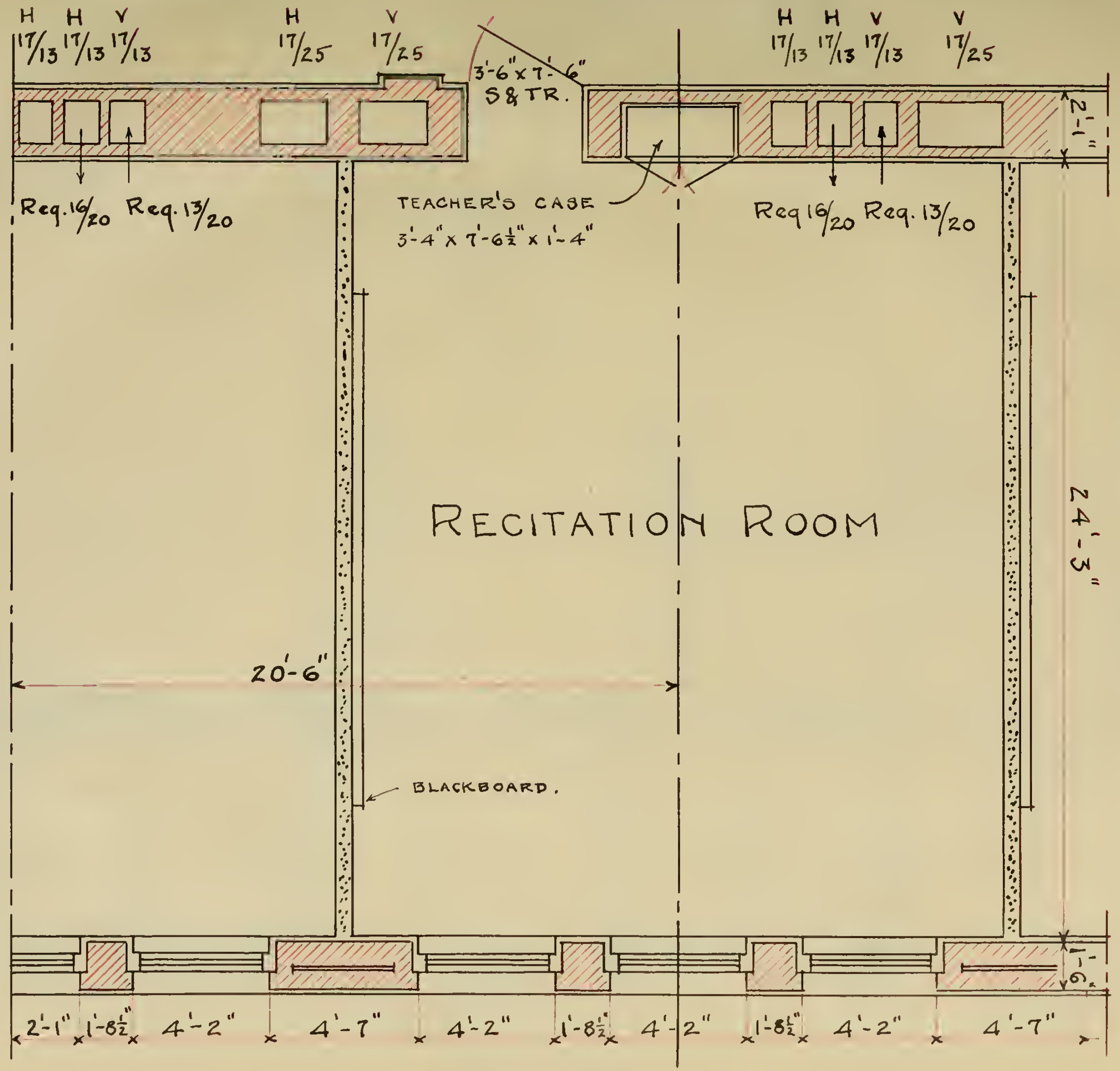
Live Load	24.25 x 20.5 x 75 x 85%	31,700 lbs.
Flooring	24.25 x 20.5 x 8.3	4,130
Joists	25 x 2 x 25 x $\frac{16}{12}$ x 4.5	7,470
Plaster	24.25 x 20.5 x 10	4,970
Tile Partition	25 x 14 x 23	8,050
I-Beam	12"- 31-1/2#	790
		57,110 lbs.

Weight of Floor in Corridors



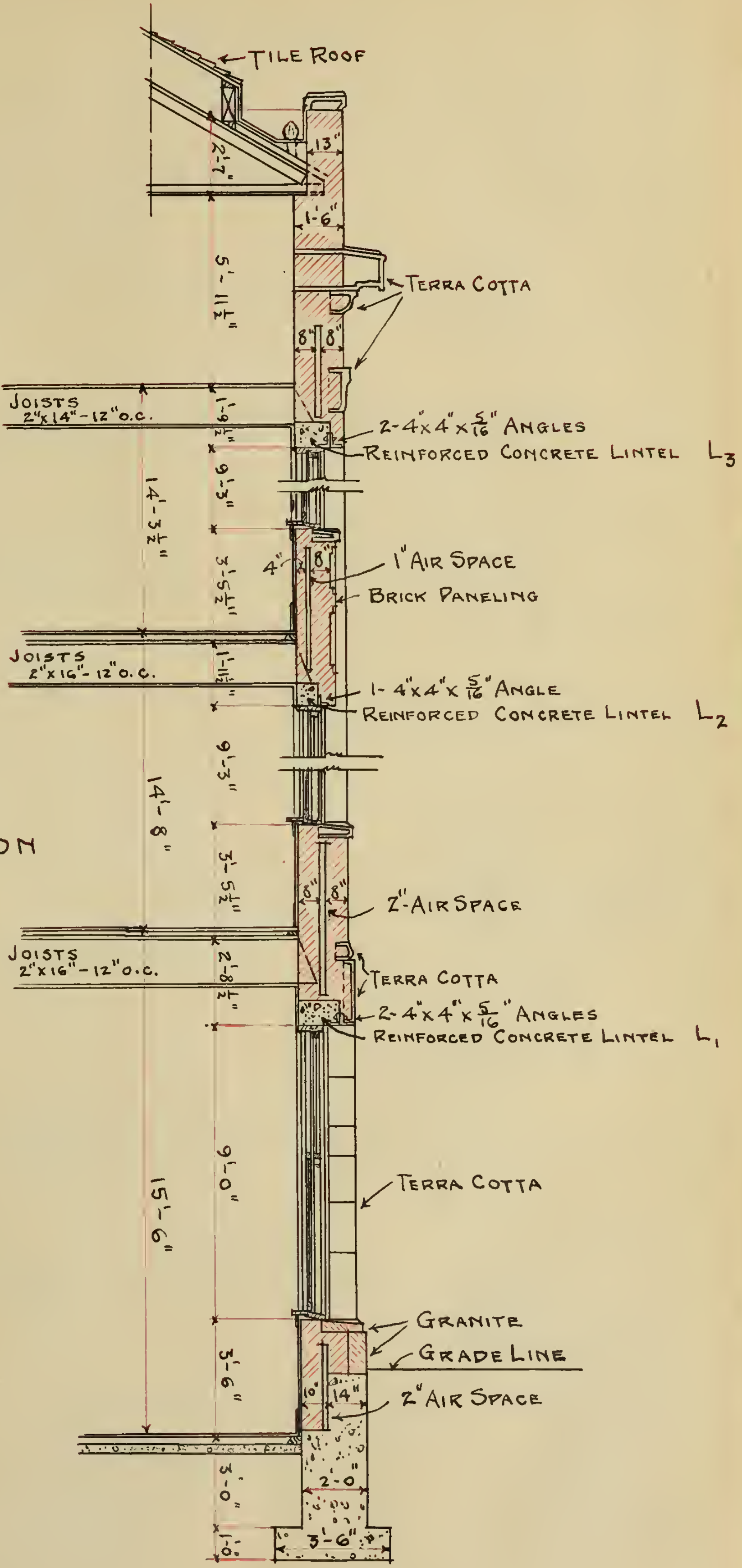
Concrete	58 lbs. per sq.ft.
Tile	30
Plaster	5
Live Load 85%	63
	156 lbs. per sq.ft.

Building With Solid Masonry Walls - In construction such that the walls carry floor and roof loads, the ordinance requires that the walls shall be at least 16" thick for the basement, first and second floors and 12" thick for the third floor. In the building studied the walls were 24" thick at the basement and 18" thick above the basement. All openings were spanned with reinforced concrete lintels.



TYPICAL SCHOOL ROOM UNIT
MASONRY CONSTRUCTION

R.E.P.



SECTION THRU WALL

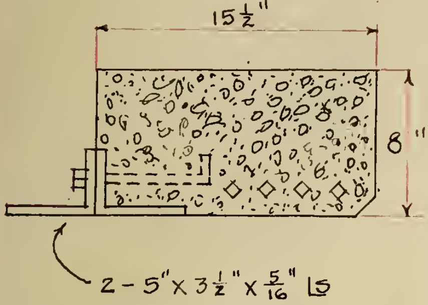
MASONRY CONSTRUCTION

SCALE 3/16" = 1'-0"

R.E.P.

Reinforced Concrete Lintels

Assume f_s= 15,000 and f_c= 600, then R = 95 and P = .007. Span = 4' 2"



Lintel L_1

Load of First Floor	1,290 lbs. sq.ft.
Masonry Wall	1,370
Windows (double hung)	75
	2,735

$$\text{Moment} = \frac{2,735 \times 4.16 \times 50}{8} = 71,000 \text{ lb. in.}$$

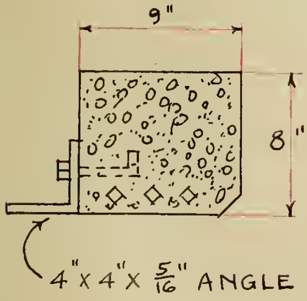
$M = Rbd^2 = 95 \times 15.5 \times 36.0 = 53,000$ lb.in.

Maximum moment of angles = 32,700

85,700 lb.in.

Area of steel required = .007 x 6 x 15.5 = .65 sq.in.

Use 4 - 1/2" square bars.



Lintel L_2

Load of Second Floor	1,290 lbs. sq.ft.
Masonry Wall	615
Windows	75
	1,980

$$\text{Moment} = \frac{1,980 \times 4.16 \times 50}{8} = 51,500 \text{ lb.in.}$$

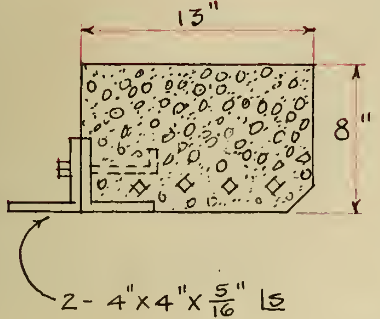
$M = Rbd^2 = 95 \times 9 \times 42 =$ 36,000 lb.in.

Maximum moment of angles = 15,500

51,500 lb.in.

Area of steel required = .007 x 6.5 x 9 = .41 sq. in.

Use 3 - 1/2" square bars.



Lintel L_3

Load of Attic Floor	1,290 lb. sq.ft.
Masonry Wall	1,770
Windows	75
	3,135

$$\text{Moment} = \frac{3,135 \times 4.16 \times 50}{8} = 81,500 \text{ lb.in.}$$

$$M = Rbd^2 = 95 \times 13 \times 45.5 = 55,500 \text{ lb.in.}$$

Maximum moment of angles = 30,300

85,800 lb.in.

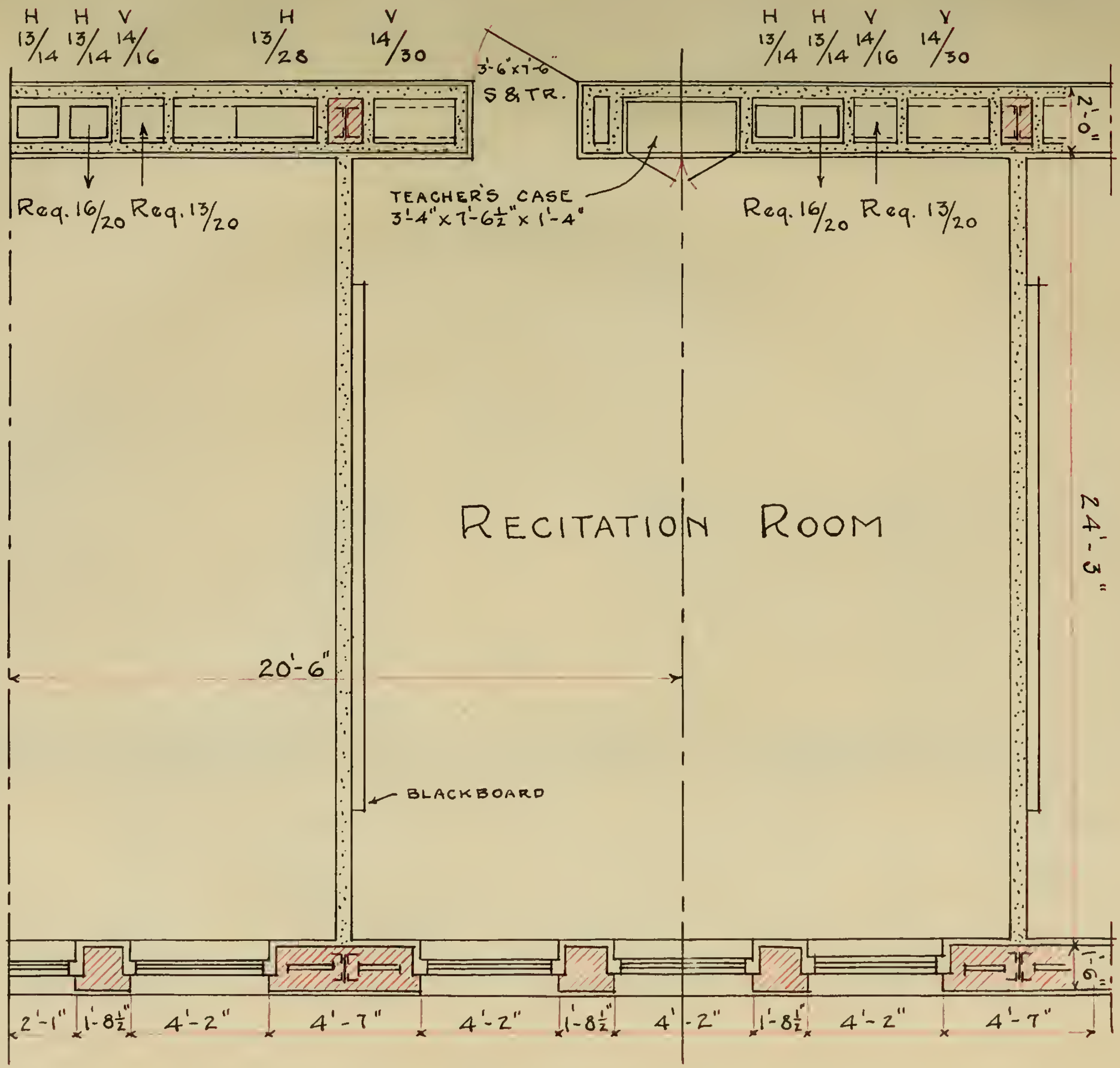
Area of steel required = .007 x 13 x 6.75 = .615 sq. in.

Use 4 - 1/2" square bars.

Steel Skeleton Structure - Because of the requirements of the ordinance and because of the fact that the general design could not be changed, the exterior wall of the steel skeleton structure could not be reduced greatly. The wall was reduced four inches in thickness all the way up, but it was necessary to put two inches of furring at the second floor.

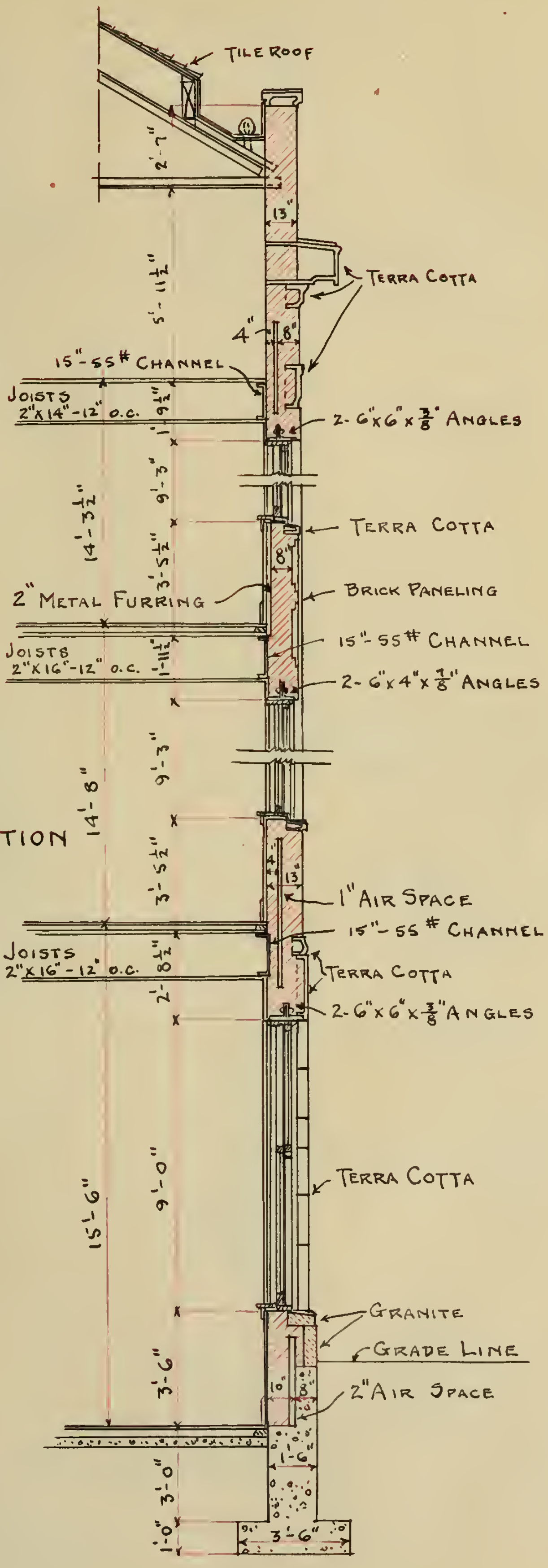
The heat ducts were reduced in size by lining them with galvanized iron, thus increasing the velocity of air in the ducts.

In construction such that the walls do not carry the weight of floors and roof, the walls may be made not less than 12" in thickness, according to the terms of the ordinance. The ground floor exterior walls will be made 18" thick and above the ground floor the wall will be made 13" in thickness, all openings being spanned by lintels composed of two angles riveted together. The interior walls in the steel skeleton structure will be made up of two rows of 3" tile.



TYPICAL SCHOOL ROOM UNIT
STEEL SKELETON CONSTRUCTION

R.E.P.

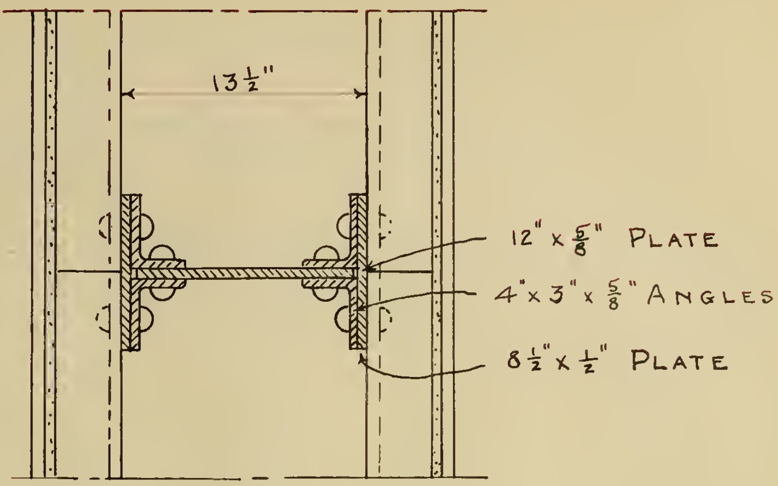


SECTION THRU WALL

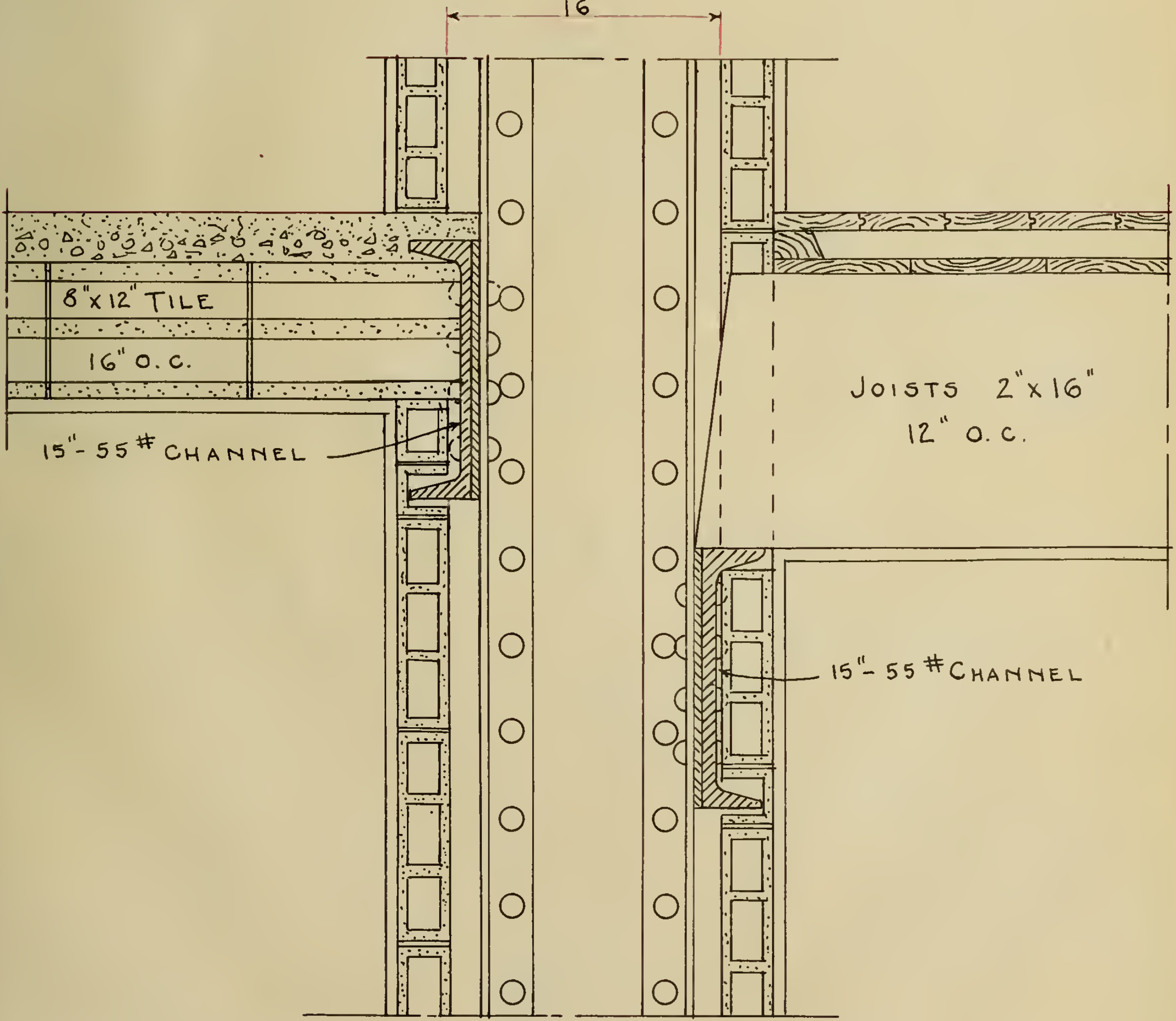
STEEL SKELETON CONSTRUCTION

SCALE 3/16"=1'-0"

R.E.F.



PLAN



DETAIL OF COLUMN – INTERIOR WALL
STEEL SKELETON CONSTRUCTION
SCALE 3/32" = 1"

R. E. P.

Loads on Columns in Exterior Walls

Columns carry roof and floor loads only,
the walls are self-supporting.

	Dead Load	Live Load	Live Load Reduced
Roof	14,650	14,950	14,950
Attic Floor	8,200	18,700	80% - 15,000
Second Floor	12,700	18,700	75% - 14,000
First Floor	12,700	18,700	70% - 13,100
Ground Floor (rests on ground)	------		------
	38,250		57,050

Load on ground floor and first floor columns = 95,300 lbs. Height 15.5 ft.

Use Plate and Angle Columns - 10" x 3/8" plate
3-1/2" x 2-1/2" x 3/8" angles

Load on second floor and attic columns = 52,800 lbs. Height 14.5 ft.

Use a 10" - 30# I-Beam

Floor Girders in Exterior Walls

Load - 28,600 lbs. Span - 20'- 6"

Use 15" - 55# Channels.

Loads on Columns in Interior Walls

Columns carry floor loads and tile interior walls.

		Dead Load	Live Load	Live Load Reduced
Attic Floor	(corridor)	15,300	12,300	
" "	(room)	8,200	18,700	80% - 24,800
Second Floor	(corridor)	15,300	12,300	
" "	(room)	12,700	18,700	75% - 23,250
" "	(interior wall)	24,250		
First Floor	(corridor)	15,300	12,300	
" "	(room)	12,700	18,700	70% - 21,700
" "	(interior wall)	24,250		
Ground Floor	(rests on ground)	-------		------
		128,000		69,750

Load on ground floor and first floor columns = 197,750 lbs. Height 15.5 ft.

Use Plate and Angle Columns - 12" x 5/8" plate
4" x 3" x 5/8" angles

Load on second floor and attic columns = 58,300 lbs. Height 14.5 ft.

Use a 12" - 31-1/2# I-Beam.

Floor Girders - Corridor Side

Load 28,620 lbs. Span - 20'- 6"

Use 15" - 55# Channels.

Floor Girders - Room Side

Load 28,600 lbs. Span - 20'- 6"

Use 15" - 55# Channels.

Heat Ducts Lined With Galvanized Iron
Are Reduced as Follows:

Assume - 1800 cu.ft. of air per pupil per hour

Room of 30 pupils requires 30 x 1800 = 54,000 cu.ft. per hour

Size of duct in brick wall - 13" x 17" = 221 sq.in.

Velocity of air in duct $\frac{54,000}{60 \times \frac{221}{144}}$ = 600 ft. per min.

By using galvanized iron ducts the velocity of the air in the duct will be increased 20% - 600 x 1.2 = 720 ft. per min.

Size of duct required $\frac{54,000}{60 \times 720}$ = 1.25 sq.ft. = 180 sq.in.

Make duct - 13" x 14"

Size of duct in brick wall - 17" x 25" = 425 sq.in.

Room of 60 pupils requires 60 x 1800 = 108,000 cu.ft. per hour

Size of duct required $\frac{108,000}{60 \times 720}$ = 2.5 sq.ft. = 360 sq.in.

Make duct - 13" x 28"

Estimate of Cost of The Parts of The Two Buildings That Differ - Four contractors were asked how to figure the brickwork of the interior wall of the building with solid masonry walls.

English Brothers, Champaign, Ill., said to figure the wall solid and multiply by the actual number of brick per cubic foot; also that one bricklayer with 1-1/2 tender would lay 1400 brick per day.

James Stewart & Company, St.Louis, Mo.,would figure the wall solid, but deduct for the teacher's cases.

V. Jobst & Sons, Peoria, Ill., figures this class of work solid, using the actual number of brick per foot; also figuring that one bricklayer would lay 600 brick per day.

Geo. A. Fuller Company, Chicago, said to get the actual cubic contents of the wall and multiply by 18 brick per cubic foot.

After considering the above information it was decided to figure the interior wall solid and multiply by 18 brick per cubic foot. It was assumed that one bricklayer with 1-1/2 tender would lay 1200 brick per day.

By supporting roof and floor loads with steel columns in the steel skeleton building the brick wall was reduced 4" in thickness over that of the solid masonry wall. It was considered that one bricklayer with 1-1/2 tender would lay 2000 brick per day on this work.

Estimate of Cost of Tile Walls Built at Champaign, Ill.

12" x 12" x 3" shale tile used. Sold by Murphy Brothers, Indianapolis.

Cost of tile per 1000	$35.00
Drayage @ 50 cents per ton 15 x 1000 x $\frac{.50}{1000}$	3.75
1 foot inch of mortar will lay 4 tile	
1 yard of mortar will lay 27 x 12 x 4 = 1296 tile	
Practice has shown that 1 yard of mortar will lay 1000 tile	
1 yard of mortar 1:3 mix will cost:	
1-1/4 yds. of sand @ 1.50 per yd. = $1.87	
9 sacks of cement @ .35 = 3.15	
	5.02
1 mason with 1-1/2 tender will lay 200 tile per day	
Wages of masons - $5.00 per day; of tenders - $2.80 per day	46.00
Profit and Insurance (10%)	8.98
Total cost per 1000 sq.ft. of wall	$98.75

12" x 48" x 3" Mackolite tile. Sold by A. B. Fireproofing Co., Chicago.

Cost of tile per 1000 sq. ft. of wall	$45.00
Drayage @ 50 cents per ton	3.75
Cost of mortar - 5/8 of $5.02 (above)	3.15
1 mason with 1-1/2 tender will lay 100 tile per day	
Cost of labor - 1/2 x $46.00 (above)	23.00
Profit and Insurance (10%)	7.49
Total cost per 1000 sq.ft. of wall	$82.39

Estimate of Cost of Brick Walls Built at Champaign, Ill.

1 bbl. of lime and 1 sack of cement to 1000 brick

2/3 of a yard of sand per 1000 brick

Lime - $1.00 per bbl.; Cement - 35 cents per sack; Sand - $1.50 per yd.

1 mason with 1-1/2 tender will lay 1200 brick per day

Cost of brick per 1000	$ 7.25
Lime and Cement	1.35
Sand	1.00
Water	.05
Labor Mason - $5.00 per day; Helpers $2.80 per day	7.66
Profit and Insurance (10%)	1.73
Total cost per 1000 brick	$19.04

1 mason with 1-1/2 tender will lay 2000 brick per day

Cost of brick per 1000	$ 7.25
Lime and Cement	1.35
Sand	1.00
Water	.05
Labor Mason - $5.00 per day; Helpers $2.80 per day	4.60
Profit and Insurance (10%)	1.43
Total cost per 1000 brick	$15.68

Estimate of Cost of Brickwork in Interior Walls

Length - 20.5 ft. Height - 47.7 ft. Cost of brick per M,- $19.04

20.5 x 47.7 x 2.08 x 18 = 36,608 brick

36.608 x 19.04 = $696.86

Cost per lineal foot of wall = $\frac{696.86}{20.5}$ = $34.00

Estimate of Cost of Excess Brickwork in Building With Solid Masonry Walls Over Steel Skeleton Structure.

(wall is reduced 4 inches of ordinary brickwork)

Length - 20.5 ft. Height - 51 ft. Cost of brick per M. - $15.68

20.5 x $\frac{1}{3}$ x 18 x 51 = 6,270 brick

6.27 x 15.68 = $ 98.32

Cost per lineal foot of wall = $\frac{98.32}{20.5}$ = $4.80

Estimate of Cost of Tile Interior Walls

Length - 20.5 ft. Height - 47 ft. Cost of Tile per M. - $98.75

20.5 x 47 x 2 = 1930 sq. ft.

7 partitions = 7 x 47 x 2 = 658 sq. ft.

1930 + 658 = 2,588 sq. ft. x 1 = 2,588 tile

2.59 x 98.75 = $255.76

Cost per lineal foot of wall = $\frac{255.76}{20.5}$ = $12.47

Estimate of Cost of Concrete Lintels

Concrete - 25 cents per cubic foot; Forms - 6 cents per square foot; Steel - 3 cents per pound.

Lintel L_1 - Length 18'- 0"

Concrete	$\frac{15.5 \times 8}{144} \times 18 \times .25$	$ 3.88
Forms	$\frac{16 + 8 + 8}{12} \times 18 \times .06$	2.88
Steel	4 x .85 x 18 x .03	1.83
Angles	2 x 8.7 x 18 x .03	9.40
		$17.99

Lintel L_2 - Length 18'- 0"

Concrete	$\frac{9 \times 8}{144} \times 18 \times .25$	2.25
Forms	$\frac{10 + 8 + 8}{12} \times 18 \times .06$	2.34
Steel	3 x .85 x 18 x .03	1.38
Angles	8.2 x 18 x .03	4.42
		$10.39

Lintel L_3 - Length 18'- 0"

Concrete	$\frac{13 \times 8}{144} \times 18 \times .25$	3.25
Forms	$\frac{14 + 8 + 8}{12} \times 18 \times .06$	2.70
Steel	4 x .85 x 18 x .03	1.83
Angles	2 x 8.2 x 18 x .03	8.84
		$16.62

Cost of lintels per lineal foot of wall = $\frac{45.00}{20.5}$ = $2.20

Estimate of Cost of Galvanized Iron Ducts

Ground Floor

2 - 13/14 21 ft. long; 1 - 13/30 - 21 ft. long; 1 - 13/28 21 ft. long

Total weight 598 lbs.

First Floor

2 - 13/14 20 ft. long Total weight 220 "

Second Floor

1 - 13/14 20 ft. long Total weight 110 "

Horizontal Ducts

1 - 20/15 40 ft. long; 1 - 20/17 - 40 ft. long;

2 - 20/6 40 ft. long. Total weight 1016 "

1944 lbs.

1944 lbs. @ 11 cents per lb. = $213.84

$$\text{Cost per lineal foot of wall} = \frac{213.84}{20.5} = \$10.43$$

Estimate of Cost of Metal Furring

Area covered - 120.05 sq. ft. Cost of furring - 11 cents per sq. ft.

120.05 x .11 = $13.20

Cost per lineal foot of wall = $\frac{13.20}{20.5}$ = $0.64

Estimate of Cost of Structural Steel

Plate and angle columns	-	$50.00 per ton, f.o.b. Champaign
Beams and channels	-	40.00 " " " "
Erection, painting, etc.	-	13.00 " "

Steel in Interior Walls

4 - 4" x 3" x 5/8" angles - 32'-4" long; 1 - 12" x 5/8" plate

1 - 12" - 31-1/2# I-Beams - 13'- 3" long;

6 - 15" - 55# Channels - 20'- 6" long

Columns - 3003 lbs. @ $\frac{63.00}{2000}$ = $94.59

Girders - 6765 lbs @ $\frac{53,00}{2000}$ = 179.27

$273.86

Cost per lineal foot of wall = $\frac{273.86}{20.5}$ = $13.36

Cost of Steel in Exterior Walls

4 - 3-1/2" x 2-1/2" x 3/8" angles - 33' 3" long

1 - 10" x 3/8" plate - 33' 3" long

1 - 10" - 30# I-Beam - 20'- 3" long

3 - 15" - 55# Channels - 20'÷ 6" long

4 - 6 x 6 x 3/8" angles - 5'- 3" long

2 - 6 x 4 x 7/8" angles - 5'- 3" long

Columns - 1992 lbs. @ $\frac{63.00}{2000}$ = $62.75

Lintels - 598 lbs. @ $\frac{63.00}{2000}$ = 18.84

Girders - 3390 lbs. @ $\frac{53.00}{2000}$ = 89.83

$171.42

Cost per lineal foot of wall = $\frac{171.42}{20.5}$ = $8.36

Total Difference in Cost per Lineal Foot of Wall

Interior Wall

Steel Skeleton Building		Solid Masonry Building	
Tile	$12.47	Brick	$34.00
Galvanized Iron Ducts	10.43		
Steel	13.36		
	$36.26		

Difference - $36.26 - $34.00 = $2.26

Exterior Wall

Steel Skeleton Building		Solid Masonry Building	
Metal Furring	.64	Concrete Lintels	2.20
Steel	8.36	Excess Brick	4.80
	$9.00		$7.00

Difference - $9.00 - $7.00 = $2.00

Results - In the building studied there are 1,074 lineal feet of exterior wall to which the difference in cost as figured are applicable. There are 640 lineal feet of interior wall for which tile walls could be substituted if steel skeleton construction were used.

1,074 x $2.00 = $2148.00

640 x $2.26 = $1446.40

--------

$3594.40

The difference in cost of the two types of building is estimated at $3594.40. The total cost of the building as built (of solid masonry construction) was $200,000. Therefore this structure if built of steel skeleton construction would cost 1.8% more than if built with solid masonry walls.

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